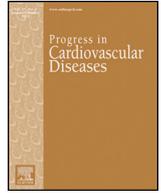




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## Global physical activity levels - Need for intervention

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### ABSTRACT

Substantial evidence shows that physical inactivity (PI) and sedentary behavior (SB) increases the risk of many chronic diseases and shortens life expectancy. We describe evidence that certain domains of physical activity (PA) in the United States (US) population have declined substantially over 5 decades. The prevalence of PI is very high worldwide, which has contributed to 6%–10% of the burden of many chronic diseases and premature mortality. Reduction or elimination of PI would likely produce substantial increases in life expectancy of the world's population. Great efforts are needed to reduce PI and SB and increase levels of PA in the US and worldwide.

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“Lack of activity destroys the good condition of every human being while movement and methodical physical exercise save it and preserve it”

[Plato 380 BCE]

Substantial evidence exists to demonstrate the profound effects of physical activity (PA) and exercise to protect against many chronic

diseases, especially cardiovascular diseases (CVD) and cancers.<sup>1–5</sup> Despite the evidence supporting PA, which has been present for decades, there remains a very high prevalence of physical inactivity (PI) and sedentary behavior (SB) in the United States (US) and worldwide.<sup>1–7</sup> Recently, great efforts have been initiated to promote PA, exercise and cardiorespiratory fitness (CRF) in efforts to reduce chronic diseases, especially CVD and premature mortality.<sup>1,2,4,8,9</sup>

In this manuscript, we review evidence indicating the decline of various domains of PA over the last 5 decades in the US, the high prevalence of PI across the globe, as well as estimations on its contribution to chronic diseases worldwide. Clearly, efforts are needed to increase PA and reduce PI/SB in the primary and secondary prevention of CVD and premature mortality.

### PA Trends in the US

Characterizing temporal PA trends across populations provides valuable information that aids in identifying barriers to becoming PA and

*Abbreviations and acronyms:* BRFSS, Behavioral Risk Factor Surveillance System; CHD, coronary heart disease; CI, confidence interval; CVD, cardiovascular disease; CRF, cardiorespiratory fitness; HMEE, household management energy expenditure; MET, metabolic equivalents; NCD, noncommunicable disease; NHANES, National Health and Nutritional Examination Survey; NHIS, National Health Interview Survey; PA, physical activity; PI, physical inactivity; SB, sedentary behavior; T2DM, type 2 diabetes mellitus; US, United States; WHO, World Health Organization.

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implementing strategies to reduce PI. Although many large scale, single site studies have provided a wealth of information that have contributed to revealing the volumes of PA necessary for health benefits and consequences of PI/SB, these studies are limited by low generalizability and may therefore not apply to all US citizens.<sup>10–12</sup> Therefore, large PA surveillance efforts have been conducted through the Behavioral Risk Factor Surveillance System (BRFSS), National Health and Nutrition Examination Survey (NHANES) and National Health Interview Survey (NHIS) with the aim of quantifying PA in different regions of the US across populations.

The most recent update to the NHIS provides sobering evidence indicating low US civilian compliance with PA recommendations, which have remained consistently low the past two decades.<sup>13</sup> Early release data from the 2017 survey<sup>13</sup> indicate that roughly half (53.8%, confidence interval (CI), 52.69–54.97%) of US adults met the 2008 PA activity guidelines for aerobic activity, with less than a quarter (23.7%, CI 22.64–24.72%) meeting both aerobic and muscle-strengthening activities. Compared to the initial survey in 1997, there has been less than an absolute 10% increase in compliance with PA guidelines. Age continues to be a prominent determinant of engaging in recommended aerobic PA levels, where younger adults (18–24 years) reported the highest compliance rate (62.2%, CI 59.33–65.05%) and older adults ( $\geq 75$  years) with the lowest (30.2%, CI 27.9–32.61%). Additionally, a greater proportion of men were found to be meeting the aerobic PA guidelines compared to women across age groups, while non-Hispanic White adults (59.2%, CI 57.96–60.42%) were more likely to meet aerobic PA guidelines compared with Hispanic (45.4, CI 42.11–48.82%) and non-Hispanic Black (46.6%, CI 44.53–48.77%) adults. Similarly, data from the BRFSS found 53.1% of Americans between the age of 18–64 years were meeting PA levels between 2015 and 2016.<sup>14</sup> PI was found to be greater in women, older adults, non-White populations, and individuals with lower incomes, lower education, and those from rural areas. A state by state examination of the prevalence of PI assessed by the BRFSS between 1984 and 2015 demonstrated a gradual decline in PI in a majority of states, even after controlling for sex, age, race/ethnicity, education, marital status, and employment status.<sup>15</sup> However, many interstate differences in the trends of PI existed over time. For example, Minnesota and Ohio experienced an increase in PI by 6.2% and 6.6%, respectively, New Mexico and Rhode Island decreased PI by –24% and –13.4%, respectively, while other states (Arizona, –24%; North Carolina, –25%; North Dakota, –26%; Utah, –20%; West Virginia, –30% and Wyoming, –26%) remained the same during the observation period.

Though large scale PA surveillance data provide valuable information regarding the evolving PA/PI trends within the US, limitations with self-reported PA habits have been regularly referenced as a primary factor that complicates our interpretation of the number of individuals meeting PA guidelines. For example, objectively measured PA data from the 2005–2006 cycle of NHANES revealed that only 9.6% of the population was meeting guidelines compared to 62% when PA was self-reported. Additionally, there was much discordance between the reported minutes spent in moderate ( $324.5 \pm 18.6$  min/week) and vigorous ( $73.6 \pm 3.9$  min/week) PA compared to device measured PA ( $45.1 \pm 4.6$  min/week and  $18.6 \pm 6.6$  min/week, respectively).<sup>16</sup> However, these stark differences between reported and device measured PA may be related to differences between objectively determined and individual perceptions of PA intensity. Many studies that objectively quantify PA intensities apply absolute accelerometer derived cutpoints that represent moderate [3–6 metabolic equivalents (METs)] and vigorous intensity ( $>6$  METs).<sup>17,18</sup> However, PA intensity can be expressed and quantified relative to an individual's maximal CRF. Previous work has demonstrated great variability in accelerometer cutpoints when individualized according to fitness level.<sup>19</sup> While there is currently limited data comparing relative intensity cutpoints to absolute cutpoints, preliminary data in older adults with type 2 diabetes found significant differences between the two methods for moderate ( $33.3 \pm 35.6$  min/day and  $7.1 \pm 9.2$  min per day,  $P < 0.05$ , respectively)

and vigorous ( $15.6 \pm 26.7$  min/day and  $0.006 \pm 0.04$  min/day,  $P < 0.05$ , respectively).<sup>20</sup> An additional factor that may contribute to the differences between reported and device measured PA could be due to individual's recalling all time spent in moderate to vigorous PA and having difficulty limiting their recall to PA performed in  $\geq 10$  min bouts. When time based restrictions (i.e.,  $\geq 10$  min) on accelerometers are removed, the total duration spent in the respective exercise intensities increase.<sup>21</sup> Now that the 2018 PA recommendations for Americans promote accumulating moderate and vigorous PA regardless of PA duration, the differences between self-reported and device measured PA may be narrowed when time based restrictions on accelerometers are removed during periods of PA monitoring. Moving forward, studies are encouraged to explore the associations between self-reported PA and device measured PA that incorporates relative PA accelerometer cutpoints and includes non-continuous PA bouts in their assessment.

Most of our understanding of national PA trends comes from surveys that inquire about leisure-time PA. However, other domains of PA, such as occupational and household activities can require significant amounts of energy expenditure and can have a favorable impact on health. Unlike the slight increase in self-reported leisure time PA discussed above, occupations that consist of light and sedentary activity have increased, whereas the prevalence of moderate to vigorous intensity occupations have decreased from 1960 through 2008.<sup>22</sup> When comprehensively assessing all forms of PA (i.e., leisure-time, transport, domestic, and occupational) Ng and Popkin noted a reduction from 235 MET hours per week in 1965 to 160 MET hours per week in 2009.<sup>23</sup> The overall reduction in PA was mainly attributed to reductions in occupational, transport and domestic activities. In this regard, we have assessed levels of household management energy expenditure (HMEE) in women,<sup>24</sup> occupational PA in men and women,<sup>22</sup> as well as the prevalence of obesity, and PA levels in mothers,<sup>25</sup> including those with children  $< 5$  years and in those with older children during the past 5 decades. Levels of HMEE have markedly declined over the last 5 decades, resulting in approximately 1800 cal less expended by women by HMEE in recent years compared with 5 decades earlier (Fig. 1), suggesting that if approximately 100 cal are burned for each mile traveled by foot, the average woman today would need to walk or jog 18 more miles/week to make up for that not expended during HMEE.<sup>24,26</sup> Regarding occupational PA levels, again marked declines have been noted in men and women (Fig. 2), which have almost totally tracked with the marked increase in the prevalence of obesity noted during recent decades.<sup>22</sup> Likewise, in analyses of mothers during the past 5 decades, marked declines have been noted in PA levels with increases in SB.<sup>25</sup> Although these changes are noted in mothers in general, the declines in PA are even more marked in those with children under the age of 5 years (Fig. 3). Since PA is the most significant contributor to levels of CRF,<sup>1–3,5</sup> these declines in PA may also adversely impact the level of CRF, which is perhaps one of the strongest predictors of prognosis, including both CVD events as well as other chronic diseases and cancers. Additionally, there is some evidence that the declines in PA in mothers could also adversely impact the offspring's levels of PA, CRF and obesity.<sup>27–29</sup>

### Global surveillance of PA levels

It is apparent that the trends of insufficient leisure-time PA across the globe is becoming more prevalent. In response, the World Health Organization (WHO) has launched an initiative to reduce PI by 10% and 15% by 2025 and 2030, respectively.<sup>30</sup> Recently, the largest global surveillance of meeting the WHO PA guidelines (150 min of moderated PA per week or 75 min of vigorous PA per week, or a combination of the two) surveyed residents of 168 countries across income groups and when available reported on trends between 2001 and 2016.<sup>31</sup> Among the 1.9 million individuals providing self-reported PA levels through the International Physical Activity Questionnaire in 2016, the global prevalence of insufficient PA was 27.5%, which was similar to the

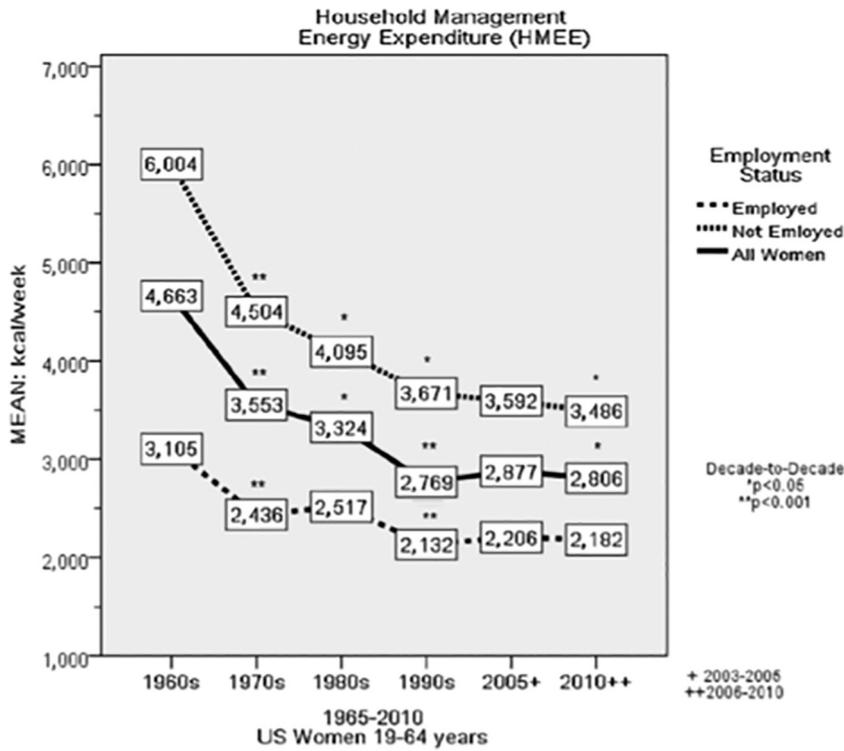


Fig. 1. Household Management Energy Expenditure per Week. This figure depicts the decade to decade change in Household Management Energy Expenditure per Week (HMEE/week) for all women and by employment status. Archer E, et al., *PLoS One* 2013.<sup>11</sup>

prevalence of insufficient PA in 2001 (28.5%). High-income Western countries were found to have the highest levels of insufficient PA (42.3%), while Southeast Asia (17.6%) and sub-Saharan African

countries (17.9%) had the lowest prevalence. Among the countries that had the lowest income, insufficient PA was half (16.5%) of prevalence levels in high-income countries (36.8%). Guthold and colleagues found an increase in insufficient PA prevalence rising in high-income countries from 2001 to 2016 (Fig. 4).<sup>31</sup> The PA phenotype of individuals within the respective income categories were inverse, such that respondents in mainly lower-income countries accumulated greater levels of PA through transport (walking and cycling) and work, whereas respondents from high-income countries reported highly sedentary occupations and a greater use of motor driven transportation. These findings are similar to previous observations within low- to middle-income countries, where individuals with higher wealth and education had lower PA levels, likely due to being employed in highly sedentary professions.<sup>32</sup> Guthold et al. concluded that if the increasing prevalence rate of PI continued on its reported trajectory, the goal of reducing the PI

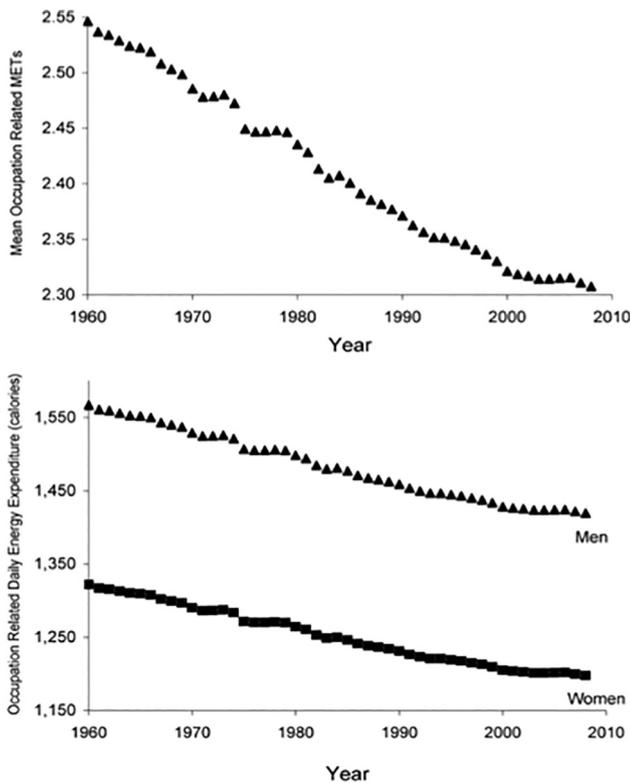


Fig. 2. Occupational METs and energy expenditure since 1960. The upper panel of this figure plots the mean occupation-related METs since 1960 and the lower panel presents the mean occupational daily energy expenditure in men and women since 1960. Church TS et al., *PLoS One* 2011.<sup>12</sup>

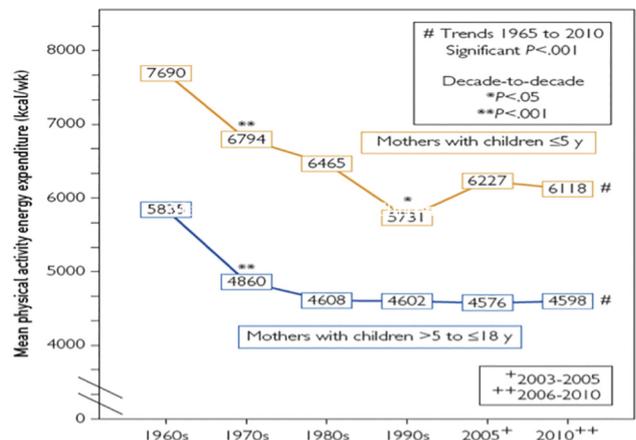
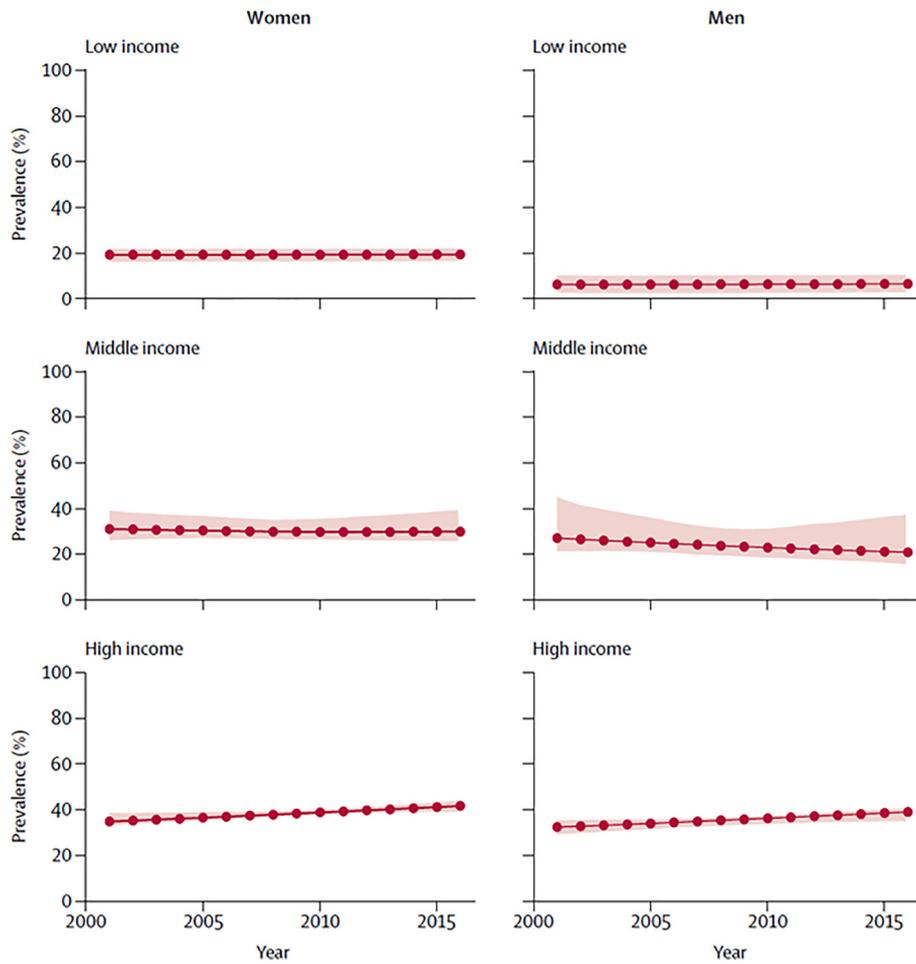


Fig. 3. Physical activity energy expenditure (mean kilocalories per week) in US mothers, 1965–2010. Archer E, et al., *Mayo Clin Proc* 2013.<sup>13</sup>

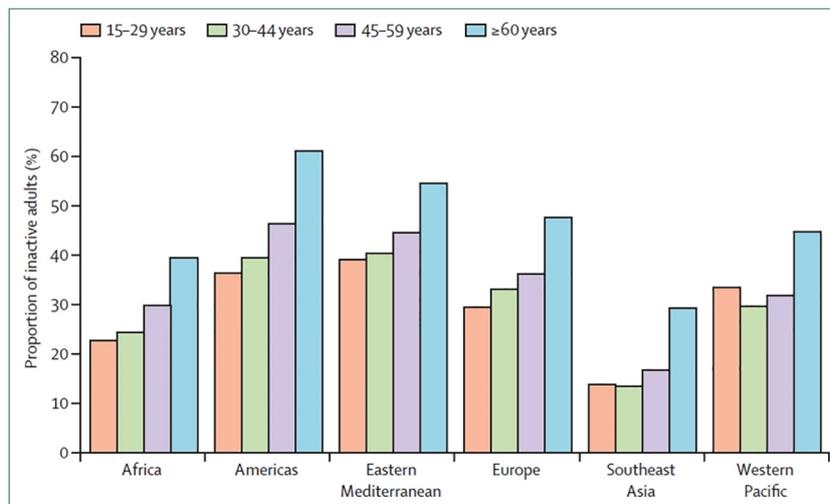


**Fig. 4.** Trends in insufficient physical activity across three income groups for men and women from 2001 to 2016, with the shaded area representing the 95% uncertainty intervals. Guthold, et al., *Lancet* 2018.<sup>31</sup>

level by 10% would not be feasible by 2025. These outcomes are particularly powerful when considering that their analysis represented 96% of the global population and that more than a quarter of all adults were PI in 2016.

Increasing age is consistently reported to have an inverse association with PA levels in both US and global (Fig. 5)<sup>6</sup> studies. Koyanagi and colleagues<sup>33</sup> examined PA levels of adults over the age of 50 in the

WHO’s Study on Global Ageing and Adult Health study. Respondents (mean age 62.4 years, 52.1% women) were stratified across 6 low- and middle-income countries as meeting or not meeting the PA guidelines using the Global PA Questionnaire. Of the 34,129 participants, 23.5% were found to be meeting the recommended PA levels. In contrast to previous reports, a country’s income status correlated weakly with meeting PA activities. Ghana, a low-income country had 22.1% of its



**Fig. 5.** Physical inactivity in age groups by WHO region. Hallal, et al., *Lancet* 2012.<sup>6</sup>

respondents meeting PA recommendations, 22% in India (lower-middle income) met the guidelines, and the upper-middle income countries (China, Mexico, Russia, and South Africa) had 24.1%, 33.8%, 20.2%, and 50.9% reporting adequate PA levels. These observations support the notion that countries, regardless of their wealth, should direct PA interventions and/or policies to older adults.

### Chronic disease burden of PI and interventions to reduce its prevalence

PI significantly increases an individual's risk of developing noncommunicable disease (NCD) and has been shown to be a more powerful prognostic measure than other traditional risk factors such as smoking, obesity, and hypercholesterolemia.<sup>34</sup> Accordingly, given the high prevalence of insufficient PA levels in large "Westernized" countries, it is no surprise that these countries have high prevalence rates of NCDs.<sup>35</sup> It has been estimated that PI is directly responsible for 6% of the global burden of coronary heart disease (CHD), 7% of type 2 diabetes mellitus (T2DM), and 10% of breast cancer.<sup>7</sup> Given the high health care costs associated with treating NCDs, Ding and colleagues estimated that the global health-care related costs attributed to PI was \$53.8 billion in 2013. This was made up of \$5 billion spent on CHD, \$6 billion on stroke, \$37.6 billion on T2DM, \$2.7 billion on breast cancer, and \$2.5 billion on colon cancer. Among the nations included in their examination, North America accumulated the highest spent at \$25.7 billion and had the highest relative expenditures of 0.84% compared to other healthcare expenditures. Furthermore, PI significantly increases risk of premature mortality and it is estimated that >5.3 million of the 57 million global deaths in 2008 were associated with PI.<sup>7</sup> If the WHO's goal of reducing PI by 10% or 25% were achieved, >533,000 or 1.3 million deaths, respectively, could be avoided each year. The elimination of PI has been predicted to increase global lifespan by a median 0.68 years.<sup>7</sup>

Reversing the rising global rates of PI and facilitating regular participation in recommended PA levels will require a multidimensional approach that targets individual, interpersonal, organizational, environmental, and policy.<sup>36</sup> The national and global PA recommendations are meant to provide the initial framework for these approaches by identifying the volume and types of PA necessary for reducing risk of morbidity and mortality. While many individuals become and or remain physically active due to their recognition and appreciation for the preventative effects of PA, many individuals require additional support to follow the PA guidelines. In recent years, the increased use of popular wearable PA devices has been one method by which individuals have aimed to become more physically active. Despite early evidence of improving PA levels through monitors<sup>37</sup> and mobile applications that foster PA adoption,<sup>38</sup> studies are needed to test the effects of these devices on long term ( $\geq 1$  year) PA adoption. These monitors have also been utilized in worksite health and wellness programs to promote regular PA.<sup>39</sup> Short term (8 week) wellness program interventions that emphasize increasing PA levels have also been shown to improve CRF, body mass index, blood pressure, blood glucose, total cholesterol and triglycerides.<sup>39</sup> These programs should be a highly attractive service for institutions to provide to their employees, particularly due to the high costs and loss of productivity associated with modifiable cardio-metabolic risk factors.<sup>40,41</sup>

The second edition of the PA guidelines for American's places emphasis on the benefits of engaging in any of the PA domains to improve health.<sup>42</sup> For instance, individuals commuting to work on at least three days of the week have been shown to have a 20% reduced risk of cardio-metabolic risk factors.<sup>43</sup> Overweight individuals starting to bike commute can even experience a significant increase in CRF within a 4-week period.<sup>44</sup> Yet, environmental barriers may significantly impair the ability of the individual to increase their active transportation to and from work as well as walk in their neighborhood. Lee et al. demonstrated cross-sectional associations between urban sprawl and

compliance with the PA guidelines, such that individuals living in areas that were PA friendly were found to be more active compared to those living in communities that were less compact.<sup>45</sup> However, within the same examination, longitudinal changes in urban sprawl was not associated with changes in PA behavior. These findings are in contrast to recent findings from the Dallas Heart Study that showed less weight gain over time by individuals living in a neighborhood that increased walkability over time, while controlling for self-selection into neighborhoods.<sup>46</sup> Given the high cost of expansive changes to existing neighborhoods, an initial goal should be to identify the most cost effective strategies of promoting daily PA through enhancing neighborhoods' built environment.

Combating any condition or behavior that is deleterious to one's health outlook is typically achieved by referring individual's to receive appropriate clinical interventions (i.e., pharmacologic, surgical procedures, or other therapies). In the US and many high-income Westernized countries, clinical and behavioral interventions are often initiated once a condition is present. For example, cardiac rehabilitation is a physician ordered PA and behavior intervention that is highly effective in reducing the risk of re-hospitalization and subsequent cardiac events for those that have been diagnosed with heart disease.<sup>47–49</sup> At this time, a physician ordered mechanism does not exist to refer patients at greatest risk for developing NCDs to receive primary prevention PA services and establish healthy lifestyle behaviors. Australia, on the other hand, has recognized the call to reimagine their healthcare system by making primary prevention services delivered by accredited exercise physiologists available to those at risk of developing NCDs.<sup>50–52</sup> Since its implementation in 2006, physician referred interventions with accredited exercise physiologist have been increasing the quality of care patients receive, thereby slowing the progression of NCDs and reducing exacerbations that would require hospitalization.<sup>53</sup> It is also apparent that physicians have embraced this model when considering that there were 80,000 referrals documented in 2010 and 620,000 services provided in 2013.<sup>54</sup> Considering the large PI prevalence rates referred to earlier, adopting this mechanism to promote early PA interventions can aid in decreasing the risk of developing future NCDs with broad national reach. Furthermore, as promoted by Arena colleagues,<sup>55–60</sup> coupling primary care services with a multidisciplinary approach that delivers consistent PA messaging and encouragement would ideally enhance the adoption of lifelong PA. There are preliminary signs that health care systems in the US are making PI detection a priority by treating PA as a vital sign.<sup>61</sup> International practitioners and policy makers must continue this momentum, take lessons from Australia's success and follow a similar path in order to facilitate broad PA adoption and begin to reverse the troubling rise of PI and NCDs.

### Conclusions

PI is highly prevalent in the US and worldwide, in adults and young people. Although the prevalence of PI is highest in women, older people and more affluent societies, the prevalence is very high in almost all groups. It appears that PI contributes to substantial burden of chronic diseases, especially CVD and premature mortality worldwide. Therefore, increasing global PA, especially that increases levels of CRF, is desperately needed in the US and worldwide.<sup>1,2,4</sup>

### Conflict of interest

There is no conflict of interest of any of the listed authors.

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